DOCUMENT RESUME

ED 307 580 CS 009 645

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TITLE The Development of Phonological Processes in Reading for Meaning.
PUB DATE Aug 88
NOTE 34p.; Paper presented at the Annual Australian Developmental Conference (5th, Sydney, Australia, August 26-28, 1988).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Beginning Reading; *Decoding (Reading); Elementary Education; Foreign Countries; Grade 2; Grade 3; Grade 4; Grade 5; *Phonics; Phonology; *Reading Comprehension; Reading Processes; Reading Research
IDENTIFIERS England; *Phonological Recoding

ABSTRACT

A study examined the importance of two phonological encoding procedures (addressed phonology and assembled phonology) in children who are learning to read and how the relative importance of these two procedures might change over the age range from six to eight. Subjects, 72 fifth, fourth, and third grade students from two inner London (England) primary schools, were asked to pretend to be teachers marking a text for inaccuracies. A later experiment investigated another grade 3 sample of 17 children in another school. Still another experiment retested some of the original subjects, and a fourth experiment used 17 second graders aged six. The sentences were constructed with either exception words (whose correct phonological forms can only be obtained using addressed phonology) or nonwords (whose phonological form must be assembled). Results indicated that both forms of phonological recoding occurred with the older children, but that phonological encoding due to addressed phonology was observed in the younger children. (Three tables of data are included, and 26 references are attached.) (RS)

The development of phonological processes in reading for meaning

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ABSTRACT

Previous research has shown that both children and skilled adult readers use phonological encoding during reading comprehension. This is indicated by the fact that both children and adults find it more difficult to reject as meaningless such printed sentences as She through a ball (which sounds acceptable) than to reject such sentences as She thought a ball (which sound unacceptable). This difference could not occur if phonological encoding played no part in sentence comprehension.

Phonological recoding of printed words can be achieved by addressed phonology (retrieval of learned pronunciations from the lexicon) or assembled phonology (conversion of print to phonology by rules specifying correspondences between letters and sounds). Which procedure causes the difficulties with sentences which sound right can be studied by using, as the critical items in such sentences, exception words (whose correct phonological forms can only be obtained using addressed phonology) and nonwords (whose phonological form must be assembled). These two types of unacceptable sentences were presented to children aged 6 to 8 years, so as to investigate (a) the importance of the two procedures for phonological encoding in children who were learning to read and (b) how the relative importance of these two procedures might change over the age range 6 to 8.

Both forms of phonological recoding occurred with the older children. With younger children phonological recoding due to addressed phonology was observed. In schools which emphasized phonics teaching younger children also showed an effect due to assembled phonology. It is concluded that teaching methods influence the acquisition of these two forms of phonological recoding. However, even in the absence of phonics teaching, skills in assembled phonology are

acquired as children learn to read so that effects due to assembled phonology are evident at 7 years of age even in children who have had no formal phonics instruction.

The role played by phonology in reading has been the subject of considerable discussion ever since reading has been studied. Clearly, phonology must be retrieved or generated in some way when reading aloud. The involvement of phonology in reading comprehension has been less easy to determine and has been debated both in single word reading tasks (Coltheart, 1980; McCusker, Hillinger & Bias, 1981) and in sentence and prose reading (Patterson & Coltheart, 1987). Errors in phrase or sentence acceptability judgments by skilled readers indicate that phonological mediation plays a part in reading comprehension. (Baron, 1973; Doctor, 1978; Treiman, Freyd & Baron, 1983). In these experiments people erroneously accept as correct such sentences as "A beech has sand", which uses an inappropriate homophone, more often than they incorrectly accept sentences such as "A bench has sand", which does not sound correct. This phonological effect suggests that skilled readers occasionally access semantic information from a phonological representation rather than directly from an orthographic input lexicon.

People are also more inclined to accept as correct two-clause sentences with a verb gap in the second clause when the verb in the first clause is phonologically acceptable but orthographically unacceptable in the second clause e.g. Cooks knead dough and plants water (Black, Coltheart & Byng, 1987). This result suggests that a phonological representation of the first clause is generated and used in the semantic and syntactic analyses performed on the second clause.

Such a possibility is also consistent with the findings of Davidson (1986) who used a rather different paradigm. Davidson presented a prose reading task one word at a time. Intermittently, a lexical decision trial occurred to visually designated text items. Facilitation of lexical decision occurred for targets which were homophones of previously presented text words; this suggested

that a phonological code for words in the text was generated and maintained for a brief period. Finally, Van Orden (1987) has also obtained evidence of phonological encoding in a single word semantic categorization task.

The manner in which this phonological code is generated has been considered in a few studies (Doctor, 1978; Doctor & Coltheart, 1980). The phonological code could arise because people retrieve the pronunciations of words from a phonological lexicon in which pronunciations of all known words are stored. Patterson (1982) termed this "addressed phonology" and distinguished it from an alternative procedure in which pronunciations are synthesized by the application of spelling-sound rules: "assembled phonology" This procedure can be used to obtain pronunciations for regular words and nonwords. Doctor and Coltheart (1980) attempted to distinguish between these two procedures in their experiments on sentence evaluation. They did so by presenting sentences containing a nonword homophone which sounded correct. If people accept such sentences as correct then the phonological code producing the error must arise from assembled phonology since nonwords do not have entries in the phonological output lexicon, and hence their pronunciations must be assembled.

Doctor and Coltheart (1980) presented children aged 6 to 10 with unacceptable sentences containing real word homophones or nonword homophones. At all ages, the children made errors to real word homophone sentences than to control sentences. Also, younger children (8 years and below) exhibited this effect with nonword homophone sentences. Doctor and Coltheart concluded that younger children rely extensively on assembled phonology in reading comprehension whilst in older children (and adults tested by Doctor, 1978) errors only occur to real word homophones implicating addressed phonology. These results suggest that assembly of phonology represents the major strategy of younger readers and is subsequently replaced by a lexical procedure.

More conclusive evidence for the operation of addressed phonology in the sentence evaluation task was provided in a study using homophones that were irregular in spelling-to-sound correspondence (Coltheart, Laxon, Rickard & Elton; 1988). For words like "through" and "mown", phonology must be retrieved from the phonological lexicon, since assembled phonology leads to incorrect pronunciations. Both adults and children aged 8 to 11 made many false positives to sentences in which these homophones were inappropriately used (Coltheart, Laxon, Rickard & Elton,1988). Children also made many errors on sentences which sounded right because they contained nonword homophones. Although error rate to sentences with nonwords diminished as a function of age and reading ability, children aged 8 to 11 made more errors when these sentences sounded right than when they did not. Adults also made significantly more errors to nonword sentences which sounded correct than to those which did not, but their error rates were very low: 4% and 1% respectively.

We offer the following interpretation of the different types of errors which can occur in reading these sentences. We will consider the skilled reader first and our proposals are based partly on the model of Patterson and Shewell (1987). The skilled reader has a well established orthographic input lexicon with entries for words encountered reasonably often in print. These entries are linked to semantic representations in a semantic system and to phonological representations in a phonological output lexicon which is used for speech production. During silent reading the skilled reader usually comprehends words by accessing representations in the semantic system activated directly from the orthographic input lexicon. However, occasionally, possibly as a result of a race between automatic processes invoked in skilled reading, the phonological representation in the phonological output lexicon may be activated prior to activation in the semantic system. This phonological code could then be

converted into an input code which activates an entry in the phonological input lexicon and then cause activation in the semantic system. The phonological input lexicon does not discriminate homophones (which are phonologically indistinguishable). Thus, |seɪl| could activate the meaning of sail or sale and context and frequency determine which meaning is likely to be activated, leading to false positive responses when inappropriate homophones are used.

We have argued that this phonologically mediated semantic access procedure causes the occasional errors adults make with sentences or phrases which sound correct (Coltheart et al, 1988). Assembled phonology could also cause phonologically mediated semantic access if the phonological output code is similarly converted into an input code. In adults, errors arising from assembled phonology are relatively rare. This could arise for two reasons. Firstly, a lexical check could establish that the nonword homophone is unacceptable. Secondly, assembly of phonology is a relatively slow process (see Patterson & Coltheart, 1987) and direct access to the semantic system from the orthographic input lexicon is likely to be achieved before phonologically mediated access consequent upon assembled phonology. Evidence from adult readers indicates that they reject sentences containing a nonword about 400 ms faster than they reject comparable all-word sentences. This is consistent with our suggestion that a check or search of the orthographic input lexicon enables the reader to reject nonword sentences at an early stage.

Let us now consider the novice reader. Younger less skilled readers are likely to differ from more skilled readers in a number of ways. Firstly, their orthographic input lexicon will have fewer entries and entries may also be represented in less detail or be incomplete. The implication of this is that unskilled readers will be less able to reject nonwords as efficiently through an orthographic search. Young readers are able to address phonology in the

phonological output lexicon at least for high frequency words (Waters, Seidenberg & Bruck, 1984). Thus, phonological mediation arising from access to semantics could occur from addressed phonology at least for high frequency homophones. There is an added reason for expecting a higher level of phonological mediation in children's reading comprehension. Unskilled readers may have less strongly established links between their newly acquired entries in the orthographic input lexicon and the semantic system. In contrast, the links between the phonological input lexicon and semantic system are well established and, of course are habitually used for spoken language comprehension.

The extent to which phonological mediation will occur from assembled phonology will depend critically on the degree of skill in applying grapheme phoneme rules. As reading skill improves these skills also increase and become more automatic. Thus, novice readers may display increasing phonological mediation arising from assembled phonology. However, this form of phonological mediation should diminish over time as the reader's orthographic lexicon expands and as orthographic checking procedures become more automatic and efficient.

Finally, phonological mediation caused by addressed phonology should also decrease over time as the reader should become more reliant on the direct route from orthographic input lexicon to semantic system.

Previous investigations of children's reading comprehension indicate much higher error rates on sentences which sould right than the error rates displayed by skilled readers (Doctor & Coltheart, 1980, Coltheart et al, 1986, 1988, Johnston et al, 1987). Could these error rates simply reflect the children's imperfect knowledge of the spelling and meaning of homophones? Several studies have indicated that although younger readers are less accurate than older readers, variations in the ability to read aloud, define and spell homophones do

not account for the large error rates obtained in printed sentence comprehension when homophones are used incorrectly (Coltheart, et al, 1986; Doctor & Coltheart, 1980; Johnston, Rugg & Scott, 1987).

Doctor and Coltheart (1980) found a substantial homophone effect with nonword sentences in 6-year-olds and that this diminished by age 9. They concluded that printed sentence comprehension is initially extensively mediated by assembled phonology as well as by addressed phonology. Later, addressed phonology causes the errors. Our data (Coltheart, et. al. 1988) however, indicated that children in the 8-11 year-old age range showed homophone effects attributable to both assembled and addressed phonology. An obvious reason for the difference between their data and ours is that, as they point out, ceiling effects occurred in their studies, where far fewer sentences were used. It is also possible that differences in the teaching methods used might differentially promote skills in assembled and addressed phonology.

Our experiments (Coltheart et al, 1988) indicated that children and adults use both addressed and assembled phonology in reading comprehension. With increases in age and reading ability the reliance on assembled phonology diminishes. These experiments did not indicate whether one procedure develops before the other as might be suggested by the Marsh et al (1980) model or whether both addresed and assembled phonology are used from the earliest stages of sentence reading. Although it would have been desirable to obtain data from younger readers, our task of 160 sentences each 6 to 8 words long was simply too difficult for children with reading ages much below 8 years. Accordingly, the studies reported here aimed to chart the development of phonological processing in reading for meaning by extending the investigations to younger readers.

The research of Seymour and Elder (1986) indicates that children taught by sight word techniques can acquire an orthographic input lexicon which is

connected to a phonological output lexicon before skills in assembly of phonology have developed. It is therefore possible that phonological mediation in reading comprehension might initially be entirely due to addressed phonology (mediated by the logographic stage). However, it has also been observed (Francis, 1984) that even children taught by a pure sight word technique acquire some knowledge of letter-sound rules simply as a result of exposure to the regularities in English orthography. Our experiments aimed to discover whether phonological mediation was primarily caused by addressed or by assembled phonology in younger readers

Experiment 1

In Experiment 1 young readers aged 6, 7 and 8 years were presented with a modified, shortened version of the task used in our earlier research (Coltheart et. al., 1988). As in the earlier study, sentences which sounded correct either did so because they contained an inappropriate exception word homophone of the correct word or because they contain a nonword homophone of the correct word. Sentences which sounded incorrect contained words or nonwords matched in graphic similarity (and other variables) to those containing homophones and homophonic nonwords. The children attended an inner London school in which the teachers used the Breakthrough (Mackay, Thompson & Schauls, 1972) method of teaching reading. Breakthrough teaches children to read and write using the Sentence Maker. In the earliest stages children make up sentences by putting words supplied on printed cards together on a stand to form sentences. They copy or make up sentences adding words from their own books or a wall chart e.g. I am big, My dad is big. At a later stage children start to compile their own dictionary of words and are encouraged to make lists of words by changing one letter. They also play games in which they might have to find words beginning

with a designated sound e.g. sh-. Thus phonics was not strongly emphasized in the first three grades and sight word techniques were used. However, in the grades 4 onwards there was more emphasis on the teaching of letter-sound correspondences which were linked to spelling instruction.

Method

Subjects. Seventy-two children from three years in an inner London primary school acted as subjects. There were 28 fifth grade children aged 8-9, 24 fourth graders aged 7-8 and 20 third graders aged 6-7.[1] The mean reading ages of these three classes were 8:11, 8:3 and 7:7 years respectively.

Tasks and Procedure. (i) Experimental Task: Eight exception word homophones, 8 visually similar control words, 8 homophonic nonwords and 8 visually similar control nonwords were selected as target items. Exception word homophones and control words were matched in frequency and were common words. Homophonic nonwords and control nonwords were selected to be homophonic to real words of comparable frequency both to each other and the exception word homophones and their controls. The stimuli were a subset of those used by Coltheart et al (1988) along with a few new items. Mean word frequencies (Hofland & Johansson, 1982) are shown in Table 1. Thus, both nonword homophones and their controls sounded like real words. Homophones and controls were also matched on length (number of letters) and on word shape (pattern of ascender and descender letters in each). They were also matched on graphic similarity (Weber, 1970) an index which assesses the extent to which pairs of letter strings share the same letters in the same sequence. The characteristics of the target items are presented in Table 1. These targets were used to construct 32 acceptable and 32 unacceptance sentences which were 4-6 words long. Half of the

INSERT TABLE 1 ABOUT HERE

unacceptable sentences sounded correct and half did not. This was true for the

16 unacceptable sentences containing words only, and also for the 16 unacceptable sentences which included a nonword. Examples of the four types of unacceptable sentences are presented below:

(i) Exception word homophone sentence: She through a ball.

(ii) Control word sentence: He thought it down.

(iii) Homophonic nonword sentence: We floo to Spain.

(iv) Control nonword sentence: The bird flor away.

Two versions of these sentences were devised. Set A included the sentences shown above, Set B reversed the assignment of homophone and control to sentence frame i.e., He through it down, and She thought a ball.

The sentences were devised so that the target item occurred approximately equally often at the beginning, middle or end of the sentence.

Thirty-two acceptable sentences were constructed and these used the target items correctly e.g., They ran through the park and He thought she was nice. For acceptable sentences based on nonword targets the correctly spelled word (which was the homophonic with the nonword) was used in an appropriate sentence, e.g. The plane flew high and The floor was hard were correct versions of (iii) and (iv) above.

These sentences were randomly ordered in a booklet arranged so that the correct and incorrect versions of a sentence occurred on different pages. Two different random sequences were constructed. The cover of the booklet contained 4 completed examples and 4 that the children had to complete before starting the main set.

The children were told to pretend they were the teacher marking sentences written by a child. Sentences which made sense and were correctly spelled were to be given a tick. Those which did not make sense and/or had spelling mistakes were to be given a cross and a ring had to be drawn around incorrect words.

The children were tested in small groups and were allowed to work at their own pace. On completion of the task a SPAR Reading Test was administered to the two older age groups and a Group Reading Test to the youngest group (Young, 1969; 1976). Both these tests contain 16 word comprehension items (picture-word matching) and 30 sentence comprehension items (multiple choice sentence completion).

Results

Unacceptable Sentences. Mean percent errors on the various types of unacceptable sentences are presented in Table 2. Analyses of variance were performed both with subjects and with stimulus items as the random factors. The fixed factors were Age Group (6 7 and 8-year olds), Sound (sounds right, sounds wrong) and Type of Target (word, nonword).

There was a significant main effect of Age Group (F (2,69) = 7.83, MS_e = 8.35, $p < .001$ for subjects and F (2,28) = 34.7, MS_e = 97.3, $p < .001$ for stimuli). Planned comparisons showed that 8-year-olds made fewer errors than 7-year-olds (t (69) = 2.08, $p < .05$ for subjects and t (28) = 3.70, $p < .01$ for stimuli) and this group performed better than the 6-year-olds (t (69)= 1.90, $p < .05$ for subjects and t (28) = 4.62, $p < .01$ for stimuli).

Sentences with nonword targets were more accurately rejected than were sentences with word targets (F (1.69) = 44.77, MS_e = 2.16, $p < .001$ for subjects and F (1,14) = 5.36, MS_e = 817.6, $p < .05$ for stimuli). Sentences which sounded right were harder to reject than sentences which sounded wrong (F (1,69) = 47.0, MS_e = 1.79, $p < .001$ for subjects,and F (1,14) = 10.52, Ms_e = 368.5, $p < .01$ for stimuli).

The interaction between Age and Sound was significant: F(2,69) = 3.16, MS_e = 1.79, $p < .05$ for subjects and F (2,28) = 6.13, MS_e = 68.4, $p < .01$ for stimuli. Simple main effects tests indicated that the effect of sound was significant only for 8-year-olds (F (1,69) = 26.17, $p < .001$ for subjects and F

(1,42) = 12.61 $p < .001$ for stimuli) and 7 year-olds (F (1,69) = 29.62, $p < .001$ for subjects and F (1,42) = 14.46, $p < .001$ for stimuli). The performance of 6-year-olds was unaffected by sound.

The interaction between Type of Target and Sound was significant for subjects only (F (1,69) = 17.55, MS_e = 1.27, $p < .001$). This reflected the fact that the effect of sound was larger for sentences with word targets than for sentences with nonword targets.

The interaction between Age and Type of Target was significant only in the stimulus analysis (F (2,28) = 4.12, MS_e = 97.3, $p < .05$).

Finally, the three-way interaction between Age, Sound and Type of Target was significant only in the subjects analysis (F (2,69) = 3.78, MS_e = 1.27, $p < .05$). This three way interaction was examined by a series of simple main effects tests which examined the effects of Sound at fixed levels of Age and Type of Target. For six-year-olds, errors on sentences with irregular homophones did not differ from errors to control word sentences. Both seven- and eight-year-olds made significantly more errors on these homophone sentences which sounded correct (t (69) = 5.84, $p < .01$ and t (69) = 7.03, $p < .01$ respectively). Similar comparisons for sentences with nonwords showed a significant homophone effect only for 7-year olds (t (69) = 1.98, $p < .05$). For 8-year-olds error rate on these sentences with nonwords was very low. 13 children made no errors at all on nonword sentences and only 3 children (who made a single error) made more errors on control nonword sentences. Thus, the 8-year-olds failed to show a homophone effect on these sentences because of ceiling effects.

We also examined the extent to which children chose the target word or nonword and put a ring around it when they correctly rejected an unacceptable sentence. Rings were almost invariably put around the target word or nonword by

eight-year olds: for 93% of 699 correct rejections. Inappropriate words were circled for 3% of sentences and rings were omitted on 4% of sentences. Inappropriate rings were put on 7% of 519 correct rejections by seven year-olds and omitted for 4% of sentences. Six-year-olds circled inappropriate words for 12% of sentences and omitted rings for 3% of sentences. These figures indicate a high level of accuracy in selecting the target word or nonword when correctly judging a sentence to be unacceptable. Younger readers were less accurate than the older ones but all three age groups performed substantially more accurately than would be expected from random selection (ie approximately 80% inappropriate rings).

Acceptable Sentences. Mean percent errors on acceptable sentences are presented in Table 2. Again, analyses were performed with subjects and with stimuli as the random factors. Age and Type of Target (homophone, control word) were fixed factors. The main effect of Age was significant in both analyses (F (2,69) = 5.42, MS_e = 13.98, $p < .05$ for subjects and F (2,60) = 31.2, MS_e = 63.4, $p < .001$ for stimuli). Eight-year olds performed more accurately than 7-year olds in the analysis over stimuli only (t (60) = 2.97, $p < .01$ for stimuli), 7-year old performance was superior to that of 6-year olds (t (69) = 2.10, $p < .05$ for subjects and t (60) = 4.86, p .01 for stimuli). Sentences with homophone targets were significantly harder than sentences with control word targets (F (1,69) = 6.31, MS_e = 1.98, $p < .05$) but this effect did not generalize over stimuli. The interaction between Age and Type of Target was not significant in either analysis.

Discussion

For sentences containing only words, seven- and 8-year-olds showed a significant tendency to accept unacceptable incorrect sentences which sounded right. It must be stressed that this homophone effect was reliable in that it

was significant in the analyses over stimuli despite the massive reduction in degrees of freedom entailed. Since the relevant words in these sentences were exception word homophones, the use of addressed phonology in sentence reading must be responsible for the homophone effect. As argued earlier, this sentence reading task demands access to semantics and syntactic analyses which are required for judgements of sentence acceptability. It would appear that in children as young as seven addressed phonology sometimes mediates semantic and syntactic processing.

These errors cannot be attributed to some general difficulty with homophones since performance on the acceptable sentences was quite accurate; and sentences with homophones were not more difficult than the sentences with control word targets. Unlike performance on unacceptable sentences, the small difference in the subjects' analysis did not generalize over stimuli and was presumably caused by one or two difficult stimuli only.

Phonological mediation in sentence reading was also found for sentences with nonword targets. Although children were generally more accurate in rejecting sentences which included nonwords, those which sounded right produced more errors than those which sounded wrong. Since nonwords do not have entries in an orthographic input lexicon linked to a phonological output lexicon, these errors must be attributable to assembled phonology. Thus, the 7- and 8-year olds must have had skills in sub-word orthographic-to-phonological conversion sufficiently accurate and automatic to provoke errors in sentence reading. We conclude that 7- and 8-year olds use both addressed and assembled phonology in reading comprehension in a manner quite comparable to that observed in 8- to 11-year olds in our earlier study (Coltheart et.al., 1988). We note, however, that errors on sentences with nonwords diminish with age as children acquire more entries in the orthographic input lexicon and acquire more detailed

representations of these entries.

In contrast, 6-year olds seemed to be unaffected by the sound of the unacceptable sentences, though they, too, were more accurate at rejecting sentences which included nonwords than those which included word targets. These results contrast with those of Doctor and Coltheart (1980) who found that 6-year olds made many errors on nonword sentences which sounded right. One possible explanation for the discrepant findings is that the children in our study were simply poorer readers. A direct comparison is not possible since Doctor and Coltheart (1980) did not assess reading ability. However, the 6-year olds in our study had a mean reading age of 7 years 7 months and this level was somewhat higher than their mean chronological age. Thus, our findings do not support their view that younger readers rely more strongly than older readers on assembled phonology. It seemed essential to study another sample of children of the same age to determine whether phonology would affect their performance.

Experiment 2

Experiment 2 investigated another Grade 3 sample from a different school. This would indicate whether perhaps the children from Grade 3 in Experiment 1 were atypical for their age and grade level.

Method

Subjects. The third grade of 17 children in a local authority school in Stevenage acted as subjects.[2] An additional child tested failed to complete the task and her data were excluded from the analyses. The mean chronological age for the class was 6:10 and mean reading age was 7:10.

Tasks and Procedure. The sentence reading task and the standardized reading test were presented as before in Experiment 1.

Results

Unacceptable Sentences. Mean percent errors on unacceptable sentences are

presented in Table 3. Again, analyses were performed with subjects and with

INSERT TABLE 3 ABOUT HERE

stimuli as the random factors. The fixed factors were Sound (right, wrong) and Type of Target (word, nonword). There was a highly significant effect of sound: more errors occurred when sentences sounded right (F (1,16) = 9.61, MS_e = 3.83, $p < .01$ for subjects and F (1,14) = 14.72, MS_e = 4.89, $p < .01$ for stimuli). Sentences with a nonword were more accurately rejected than were sentences with word targets (F (1,16) = 19.34, MS_e = 1.22, $p < .001$ for subjects and F (1,14) = 3.81, MS_e = 15.89, $p < .07$ for stimuli). The interaction between Sound and Type of Target was not significant in either analysis.

Again, the extent to which children put rings around inappropriate words, or omitted rings, for correctly rejected sentences was examined. Inappropriate rings were put on 7% and omitted on 3% of sentences.

Acceptable Sentences. Mean percent errors on sentences with homophones and control targets are presented in Table 3. A related groups t - test indicated that these error rates did not differ significantly for subjects and, consequently, a stimulus analysis was not performed.

Discussion

Experiment 2 on the six-year olds from Stevenage indicated that children of that age can be susceptible to the phonological effects observed in seven-and eight-year olds. The Stevenage children demonstrated effects of both addressed and assembled phonology in reading comprehension. They, also, like older children were more accurate at rejecting sentences with nonwords.

These children were similar in age to the London children and their overall reading performance on the standardized test was only slightly better.

Nevertheless, their performance on the experimental task was more like that of children a year older in the London school sample. It seemed possible that perhaps the London six-year olds might display this more systematic pattern of performance a few months later. Consequently, they were re-tested about 3 months later.

Experiment 3

Method

Subjects. 19 of the 20 children in the third grade from Experiment 1 were available for testing approximately 3 months later. Their mean reading age was now 7:8.

Tasks and Procedure. These were the same as those used in Experiment 1.

Results

Accuracy in responding was compared on the two occasions. Mean total correct responses on the first test was 41.2 and it was 45.4 on the second test for the 19 children who completed the task on both occasions. This improvement in accuracy was highly significant (t (18) = 3.70, SEM.= 1.12. $p < .002$). Further analyses of performance on the various types of sentences are reported below.

Unacceptable Sentences. Mean percent errors on unacceptable sentences are shown in Table 3. Analyses of variance were performed over both subjects and stimuli as in Experiment 2. Sentences which sounded right were harder to reject than sentences which sounded wrong (F (1,18) = 6.61, MS_e = 4.03, $p < .05$ for subjects and F (1,14) = 11.76, MS_e= 5.87, $p < .01$ for stimuli). In the analysis over subjects, sentences with nonwords were more accurately rejected than sentences with word targets (F (1,18) = 9.25, MS_e = 1.37, $p < .01$).

The interaction between Sound and Type of Target was also significant (F (1,18) = 9.25, $p < .01$ for subjects and F (1,14) = 4.48, MS_e = 5.87, $p < .05$

for stimuli). Simple main effects tests indicated that the effect of sound was significant only for sentences with word targets (F (1,36) = 13.26, $p < .01$ for subjects and F (1,14) = 15.37, $p < .01$ for stimuli). Thus, the homophone effect was confined to sentences with word targets. The children were a little more accurate than on first test in circling target words in sentences since inappropriate rings were put in 10% of correct rejections and omitted for 3%.

Acceptable Sentences. Percent errors on acceptable sentences are shown in Table 3. A related groups t test over subjects indicated that error rate to homophone and control word sentences did not differ significantly. Thus, a stimulus analysis was not performed.

Comparisons of First and Second Tests

Performance on both occasions was compared in a further analysis. This included Testing Occasion ((1st, 2nd Test), Sound (sounds right, sounds wrong and Type of Target (word, nonword) as within -S factors. Accuracy (high, low) was included as a between - S factor. The least accurate subject was excluded and the remaining 18 Ss were divided into two groups of 9 on the basis of overall accuracy in performing the task at first test.

This analysis yielded a highly significant effect of accuracy ($F(1,16)$ = 19.76, MS_e = 6.125, $p < .001$). The effect of Sound was significant (F (1,16) = 4.74, MS_e = 6.007, $p < .05$) and so was the effect of Type of Target (F (1,16) = 27.96, MS_e = 0.955, $p < .001$). Performance was more accurate on the second test, but the effect of Testing Occasion only approached significance ($F(1,16)$ = 4.17, MS_e = 1.639, $p = .055$).

This interaction between Sound and Type of Target was significant ($F(1,16)$ = 6.25, MS_e = 1.441, $p < .05$). Simple main effects tests indicated that the homophone effect was significant only for sentences containing exception word

homophones : $F(1,32) = 9.32$, $p < .01$). The homophone effect was not significant for sentences containing nonwords ($F < 1$).

The interaction between Accuracy and Type of Target was also significant : $F(1,16) = 19.67$, $MS_e = 0.955$, $p < .001$. Simple main effects tests showed that only the more accurate readers rejected more nonword sentences than they did all-word sentences ($F(1,16) = 47.26$, $p < .001$).

No other interactions were significant, although the three-way interaction between Accuracy, Homophony and Type of Target approached significance ($F(1,16) = 3.26$, $p = .087$).

Discussion

The 6-year-old children from Experiment 1 performed more accurately when re-tested a term later. They also now made significantly more errors on sentences which sounded right than those which sounded wrong. However, this homophone effect was confined to all-word sentences. Since these employed irregular homophones it can be concluded that the children now used addressed phonology to access meaning. In the case of nonword sentences, rejection rates were higher than formerly. Skills at assembled phonology appeared to be lacking since the children were unaffected by the sound of the sentences with nonword homophones. This pattern of performance accords well with those who claim that direct access and addressed phonology develop earlier than do skills in assembled phonology (e.g., Barron, 1986; Seymour and Elder, 1986).

When we compared performance on the first and second occasions, accuracy overall had increased. However, testing occasion did not interact significantly with any of the variables suggesting that the homophone effect with exception words may have been present to a less marked extent even at first test.

The differing results for the Stevenage and London six-year olds need further consideration. It is unlikely that the minor differences in reading age (only 2 months) can explain the apparent difference in the use of assembled phonology. It more likely that differences in teaching methods may have resulted in a superior development of the skills required to assemble phonology. Discussions with the teachers of these two classes seemed to support this second suggestion. The London school used the Breakthrough method (Mackey,Thompson & Schaub,1972)which emphasizes the acquisition of sight words many of which are elicited from the children who are encouraged to construct their own sentences. The Stevenage school used a mixture of "look-and-say" methods and phonics. Their phonics teaching appeared to be more extensive and included systematic training on letter digraphs displayed on wall posters which were used to construct dictionaries. This greater emphasis on phonics may have led to the more marked development of skills in asembled phonology.

Experiment 4

The possible role of phonics teaching was further studied in Experiment 4. London School 2 extensively uses a phonics training scheme known as Letterland (Wendon, 1986). This scheme is designed for use from the first year of school during which single letter-sound correspondences are taught using pictures of letters paired with a a person, creature or animal sharing the letter sound eg Sammy the Snake. The children copy these and colour them in colouring books and learn rhymes and songs about the letters. In the second year of school vowel and consonant digraphs are systematically taught together along with the words which include them. This training makes use of the single letter-sound already learned. eg Sammy the snake goes "ss" and Harry the Hatman whispers because he doesn't like noise. So when they meet he says "sh..." ie S + H -> SH. This training is coupled with th_ e of a reading scheme, sight words and writing

generated by the children. Thus, a mixture of methods are used with an emphasis on phonics training from the earliest stages. It, therefore, seemed of interest to test the second grade children taught by these methods, since these children had had such extensive early training in the application of grapheme - phoneme correspondences..

Method

Subjects. 17 Second grade children aged six acted as subjects. Although only in the second year this group had mostly turned six since testing was conducted right at the end of the second year. Their mean age was 6:9 and mean reading age was 6:7 on the Group Reading Test, a level somewhat lower than in the earlier samples.

Tasks and Procedure. These were identical to those used in the earlier experiments.

Results

Unacceptable Sentences

Mean percent errors on unacceptable sentences for London School 2 six-year-olds are presented in Table 3. Again, analyses of variance over subjects and over stimuli were performed. Sentences which sounded right were more difficult to reject than sentences which did not ($F(1,16) = 11.33$, $MS_e = 3.38$, $p < .01$ for subjects and $F(1,14) = 24.61$, $MS_e = 3.57$, $p < .001$ for stimuli). No other effects were significant in either analysis.

Inappropriate rings occurred on 19% of correctly rejected sentences and rings were omitted on 5%.

Acceptable Sentences. Mean percent errors on acceptable sentences are presented in Table 4. A related groups t test indicated that these error rates did not differ significantly.

Discussion

London School 2 children were reading at a level about a year below than that of the other two infant groups which had an extra year of school. Their performance on the experimental task, though slightly lower in accuracy than that of the older infant children, was quite systematic. Sentences which sounded correct were more likely to be accepted by them than were sentences which did not. Furthermore this homophone effect occurred to a comparable extent on both irregular homophones and nonword homophones. Thus, these children were displaying the use of both addressed and assembled phonology in reading comprehension. Their performance displayed more phonological mediation than that of London School 1 third grade children on their first test. This suggests that the development of the use of addressed and assembled phonology is not critically dependent on having attained a reading age of approximately 7:10 as suggested by the results of Experiments 1 and 2.. Instead, it appears that teaching method may actively promote the early acquisition of assembled phonology which then contributes to reading comprehension. In the absence of much explicit phonics teaching addressed phonology is likely to be manifest earlier than assembled phonology. London School 1 children initially showed no influence of phonology on reading for meaning. Three months later addressed phonology was used to access semantics. Children in the subsequent year of the school appeared to have acquired assembled phonology despite the relative lack of emphasis on phonics teaching. The results of these experiments suggest that teaching methods may have caused, in part, the younger children in Doctor and Coltheart's (1980) experiment to display the use of assembled phonology early on. The conclusion that beyond 8 or 9 years children cease to rely on assembled phonology was probably premature and based on ceiling effects in their data. In our data on 8 year-olds in Experiment 1 there were also ceiling effects

obtained on sentences containing nonwords. However, in our earlier study (Coltheart et al. 1988) when children were presented 20 sentences of each type, we found that 8-, 9- and 11-year olds made more errors on sentences with nonword homophones than on sentences with orthographically matched controls. Similarly Johnston et al (1987) found a nonword homophone effect with normal readers aged 7, 8 and 11 years and poor readers aged 8 and 11 years. Averaging error rates across the various age and ability groups in the Johnston et al (1987) study indicates quite similar overall error rates to those in Experiment 1: 28% for nonword homophone and 18.5% for control nonword sentences. Johnston et al (1987) also found, as we did, rather larger homophone effects when sentences used real word homophones.

We conclude that phonology plays an important role in sentence comprehension in children from an early stage in reading acquisition. During the second or third year of reading instruction, children show the influence of addressed phonology in sentence reading by making errors on sentences with exception word homophones. The involvement of assembled phonology is shown by errors on sentences with nonword homophones. Assembled phonology also produces errors in children aged 8 to 11 years across a wide range of ability. In younger children aged 6 years, assembled phonology only seems to influence reading comprehension when there has been relatively extensive phonics training. However, even in children not given much phonics training, skills in assembled phonology are acquired as reading skill improves progresses so that by age 7 assembled phonology can cause errors in sentence comprehension. As discussed earlier, there is much evidence to indicate that in the adult skilled reader phonology continues to mediate comprehension and addressed phonology is chiefly implicated with assembled phonology playing a minor part (Coltheart et al. 1988; van Orden, Johnston & Hale, 1988. We conclude that from an early period in reading acquisition children's reading comprehension involves similar processes,

and that the differing use of these processes at an early age is in part attributable to the specific methods used to teach reading.

Table 1

Characteristics of Words and Nonwords used as Targets in Experiments 1-4

	Homophones	Control Words	Homophonic Nonwords	Control Nonwords
Mean Word Frequency	203	213	222	225
Mean Graphic Similarity	547	523	482	483
Mean Length (letters)	4.9	5.1	3.9	3.9

Table 2

Mean Percentage Errors on Acceptable and Unacceptable Sentences in Experiment 1.

	Unacceptable Sentences			
	With Words		With Nonwords	
Age	Sound right	Sound wrong	Sound right	Sound wrong
6 years (n=20)	51.3	44.4	40.6	35.0
7 years (n=24)	51.6	25.5	30.7	21.9
8 years (n=28)	47.3	18.3	13.8	8.5
Overall Mean (n=72)	49.8	28.0	26.9	20.3

	Acceptable Sentences	
Age	Homophone	Control
6 years (n=20)	29.7	25.9
7 years (n=24)	19.8	14.8
8 years (n=28)	13.2	10.7
Overall Mean (n=72)	20.0	16.3

Table 3

Mean Percentage Errors on Acceptable and Unacceptable Sentences in Experiments 2, 3 and 4.

	Unacceptable Sentences			
	With Words		With Nonwords	
	Sound right	Sound wrong	Sound right	Sound wrong
Experiment 2: Stevenage 6-year olds (n=17)	51.5	28.6	32.4	18.4
Experiment 3: London School 1 2nd Test 6-year olds (n=19)	54.0	29.6	34.3	29.0
Experiment 4: London School 2 6-year olds (n=17)	54.4	38.2	58.1	36.8

	Acceptable Sentences	
	with Homophone	with Control Words
Experiment 2: Stevenage 6-year olds (n=17)	19.1	17.6
Experiment 3: London School 1 2nd Test: 6-year olds (n=19)	21.7	21.4
Experiment 4: London School 2 6-year olds (n=17)	26.1	27.9

Footnotes

1. Two fourth grade children (RA < 7:1) and nine third grade children (RA < 6:5) failed to complete the task. Although these children were amongst the poorest readers in their classes, others with comparable standardized test scores did complete the experimental tasks in both classes.

2. We would like to thank Mary Rickard for collecting the data for Experiment 2.

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